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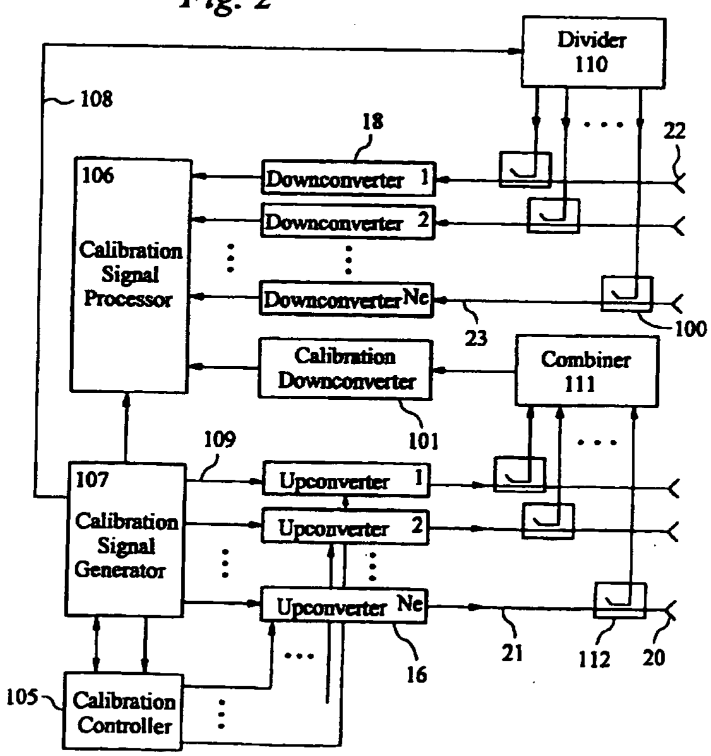
(54) Abstract Title
Antenna array calibration

(57) An antenna array, particularly for a CDMA mobile telecommunications system is calibrated live by injecting a calibration signal which is coded orthogonally to communication traffic signals. This permits regular and reliable calibration to be performed. To calibrate receiver circuits a spread code signal is injected via couplers 100 into the downconverters 18 connected to each receive array element 22. Processor 108 calculates calibration corrections. For transmitter circuits, generator 107 injects the calibration signals which are extracted by couplers 112, combined 111, downconverted 101 and supplied to processor 108.

Fig. 2



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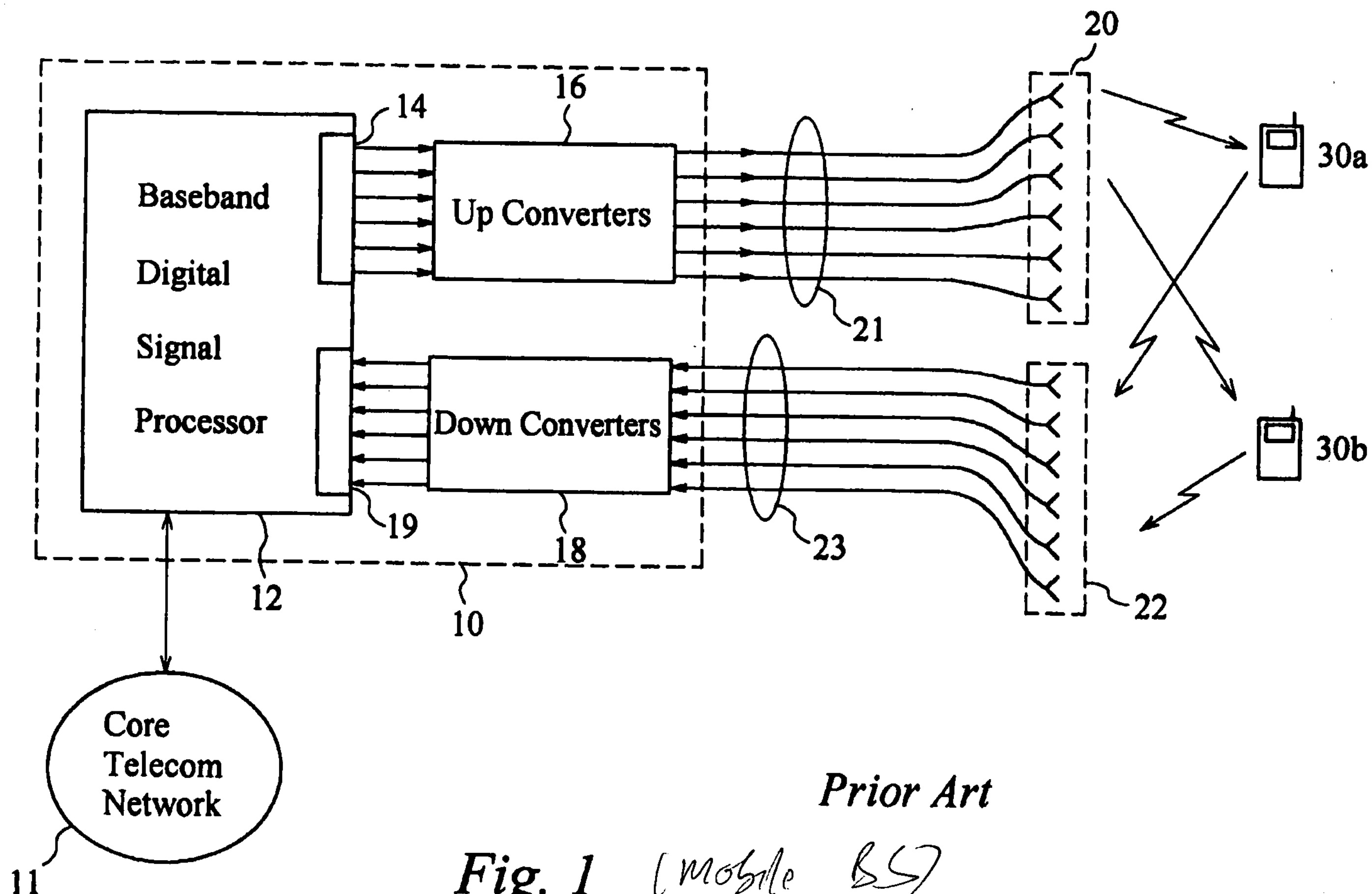
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

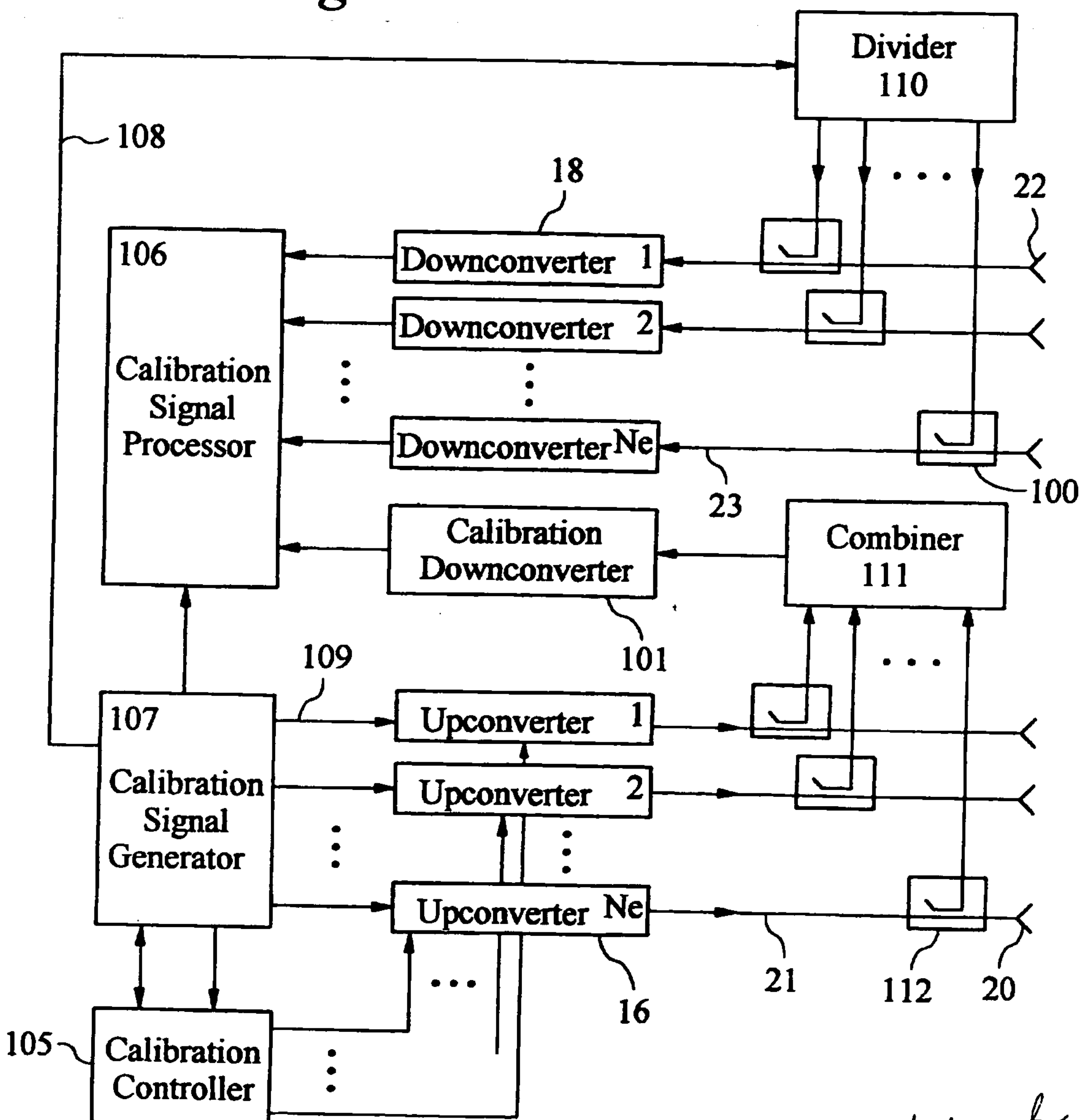


Prior Art

Fig. 1 (Mobile BS)

20: Transmission antenna array
22: Receiver

Fig. 2



108 : calibration signal processor

ANTENNA ARRAY CALIBRATION

The present invention relates to the calibration of antenna arrays and associated electronics, particularly, but not exclusively, for use in mobile telecommunications, particularly Code Division Multiple Access (CDMA) systems.

It is known that an antenna array in which the array elements are individually controllable can offer advantages over a single antenna. For example, in mobile communications signals can be directed specifically to a mobile device, giving improved gain. Commercial systems using antenna arrays having a plurality of antenna elements coupled to individual receiver and transmitter electronics are well known.

A known problem with such antenna arrays is that, owing to manufacturing tolerances, dissimilar cable lengths and differences in active components in transmitter and receiver electronics, there may be differences in phase shift or gain between individual elements. That is, if an identical signal is supplied to all transmitters, the signals radiated from the corresponding antennae may differ in amplitude and/or phase. Similarly, when identical radio signals are received by all antennae in an array, the signals output by the receiver electronics may differ in amplitude and/or phase.

To overcome this problem, it is known to store a calibration vector, for example containing a series of complex multiplication coefficients, defining the characteristics of the antenna array and associated electronics. The determination of these characteristics often requires sophisticated calibration equipment and basic calibration is often performed only once on installation or manufacture of the array, or a class calibration vector is often assigned to equipment of a particular type.

There have been several proposals for the calibration of phased arrays where

a calibration signal is passed in place of a normal signal, an example of which is disclosed in WO-95/34103; these are not suitable for use in a live communication system where calibration is desired without interruption of communication.

There are also several proposals which rely on a remote calibration device to complete calibration of an antenna array. US-A-5546090 describes a transponder for use in calibration of an antenna array which receives signals transmitted from the antenna array and returns them to the same array so that the calibration electronics may be coupled directly to the array and the transponder itself may be a relatively simple and portable device. The problem remains that the use of a separate remote antenna in the calibration step, even if a relatively simple device, complicates the calibration procedure and precludes regular calibration.

EP-A-713261 discloses an arrangement for calibration of an antenna array for a satellite in which a "small" (low power/limited bandwidth) probe signal is transmitted so as not to cause unacceptable interference with other signals. The use of a lower power probe signal may make measurement troublesome (a dedicated remote calibration station is described) and may require longer integration times.

GB-A-2313523 describes a system for calibrating error-correction and calibration circuitry, particularly in a GSM system, by injecting a low-power broadband signal into error-correction circuitry which is isolated from the main transmitter/receiver electronics chain by means of a directional coupler. It is to be noted that this disclosure is concerned specifically with calibration of in-built calibration circuitry, and does not deal with the problem of basic calibration of up-link or down-link receiver or transmitter electronics used for live signals.

It has been appreciated pursuant to the present invention that, particularly

in the context of CDMA systems and particularly at higher frequencies, it would be desirable to provide some means of performing "live" calibration of the transmitter and/or receiver chains used for actual transmission and reception of information, as this may enable more frequent and reliable calibration.

It is thus a particularly preferred aim of the invention to provide a method and apparatus suitable for "live" calibration of an antenna array, that is calibration that can be performed whilst the array is in use. It is another preferred aim to provide a method and apparatus which does not necessarily require a separate remote calibration device or transponder.

According to a first method aspect, the invention provides a method of calibrating at least a portion of a chain of transmitter or receiver components coupled to an element of an antenna array and communicating a plurality of communication traffic signals with the antenna array element, the communication traffic signals being coded according to a given coding scheme to be substantially mutually orthogonal, the method comprising: | orthogonal

injecting a calibration signal into the chain, the calibration signal being coded according to said given coding scheme to be substantially orthogonal to said communication traffic signals;

extracting the injected signal; and

calibrating said portion based on the extracted signal.

In this way, normal operation of the array can be substantially unaffected and transmission or reception of the communication traffic signals can continue substantially uninterrupted during calibration. Another advantage is that regular or quasi-continuous calibration of the "live" transmitter and receiver electronics can be performed without preventing use of the array for communication traffic. A further important advantage is that the calibration signal can be processed by the circuitry to be calibrated in a near-identical manner to communication traffic and should experience near-identical phase

phase & group amplitude distortion

and amplitude distortions, so calibration should be more accurate; it has been appreciated pursuant to the invention that in prior art arrangements in which a calibration signal is of a different nature (for example lower power, narrower bandwidth, different frequency) to communication signals, it is conceivable that the calibration signal will experience different phase or amplitude distortions, particularly due to non-linear elements in the receiver or transmitter chains, leading to inaccurate calibration.

References to signals being substantially mutually orthogonal preferably imply that the signals cause substantially no interference with each other.

In a first apparatus aspect, the invention provides apparatus for calibrating at least a portion of a chain of transmitter or receiver components of communication apparatus arranged for coupling to an element of an antenna array to communicate a plurality of communication traffic signals with the antenna array element, the communication traffic signals being coded according to a given coding scheme to be substantially mutually orthogonal, the apparatus comprising:

means for injecting a calibration signal into the chain, the calibration signal being coded according to said given coding scheme to be substantially orthogonal to said communication traffic signals;

means for extracting the injected calibration signal; and

means for determining at least one calibration parameter for said portion based on the extracted signal.

In a second apparatus aspect, the invention provides communication apparatus arranged for coupling to an antenna array having a plurality of elements, the apparatus comprising:

a plurality of chains of transmitter components and receiver components, each chain being arranged for coupling to a respective element of the antenna array and arranged to pass a plurality of communication traffic signals to or from the antenna array element, the communication

traffic signals being coded according to a coding scheme to be substantially mutually orthogonal;

means for injecting a calibration signal into the chain, the calibration signal being coded according to said coding scheme to be substantially orthogonal to said communication traffic signals;

means for extracting the injected calibration signal; and

means for determining at least one calibration parameter for said portion based on the extracted signal.

Preferably, the signals are injected and extracted locally. References to the injecting and extracting being performed "locally" are intended to exclude arrangements in which a remote calibration device or transponder is employed; preferably, the calibration apparatus is integrated with the apparatus to be calibrated. integrated

The antenna array is preferably arranged for communication over a plurality of defined (physical or logical) channels and the calibration signal is preferably injected into one or more channels which are not used for communication traffic.

Most preferably, the antenna array is arranged for use in a CDMA communication system, and the calibration signal is coded with one or more spreading codes different from codes assigned to communication traffic. spreading codes

In the case of a CDMA system, at least for calibration of a transmitter side, preferably the calibration signal is injected using a single Orthogonal Variable Spreading Factor (OVSF) short code, different from OVSF codes used for communication traffic. This can avoid the need to use multiple OVSF codes for calibration and avoids interference with user traffic. There are only a limited number of available OVSF codes on the downlink side. Since the uplink uses scrambling codes to distinguish mobile devices, the constraints are less severe but preferably only a single OVSF and scrambling code

combination is used for calibration of the receiver side.

Because the same coding scheme is used as that used for communication traffic, the hardware required for calibration can be similar to that required for demodulation of communication signals, simplifying design and testing.

The invention may be applied independently on one or both of the receiver and transmitter sides of the antenna array.

Preferably, in the case of calibration of the transmitter-side electronics, the short code is further modulated with a data sequence which varies between elements of the antenna array, selected so that, at least over a complete integration period, the combination of OVSF and data sequences for each transmitter chain are mutually orthogonal. In this way, the signals from the transmitter-side circuitry can be combined and down-converted using a single converter, without requiring separate OVSF short codes.

On the transmitter side, preferably individually identifiable signals are supplied to each of a plurality of transmitter chains, each coupled to respective array elements, preferably substantially simultaneously. This enables the signals to be combined and extracted using a single receiver. This avoids the need for multiple converters and allows simultaneous calibration of the elements.

Preferably, in the case of calibration of the transmitter-side circuitry, the calibration signal is injected in the digital domain, prior to digital to analogue conversion. Also, in the case of calibration of transmitter-side circuitry, the calibration signal is preferably sampled by means of a radio frequency coupling coupled to a transmission line supplying signals to a corresponding antenna element.

Preferably, in the case of calibration of receiver-side circuitry, the calibration

signal is injected by means of a radio frequency coupling coupled to a transmission line receiving signals from a corresponding antenna element. Also, in the case of calibration of the receiver-side circuitry, the calibration signal is preferably extracted in the digital domain, after analogue-to-digital conversion of the received signal.

Injection or extraction in the digital domain as indicated above may facilitate processing.

Injection or extraction of the radio-frequency signal as indicated above may avoid the need for separate antennae which may be cumbersome to install or which may interfere with signals transmitted from or received by the antenna array. The couplings are preferably provided physically close to each antenna element, for example at the antenna side of any long cable runs, to minimise any variable factors between the antenna elements and the couplings. Alternatively, a separate antenna may be provided to couple the radio frequency signals to the antenna elements. separate

hourly, minute, second

Preferably the calibration signal is injected and a measure of calibration is obtained regularly (for example at least hourly, better at least about every minute, preferably at least about every 10s, more preferably at least about every second) or substantially continuously. It is found that if calibration is performed at least about 10 times per second, or more preferably at least about 50Hz, preferably at about 100Hz, drifts in phase of local oscillator signals generated within each transmitter or receiver can be tracked.

Typically communication traffic signals will be transmitted in frames, usually of less than 1 second duration (typically 10ms or 20ms). The calibration signal is preferably injected substantially every predetermined number of frames (during normal operation; this may be suspended under certain exceptional conditions such as during testing or maintenance or during particularly heavy communication traffic conditions), for example preferably

at least about every 100 frames, preferably at least about every 10 frames and more preferably about every frame, or every other frame. Frames may be grouped into super-frames (for example of 720ms duration), and calibration may conveniently be performed approximately every super-frame.

This regular calibration can enable small drifts in calibration, for example due to temperature changes in the equipment, to be tracked reliably, and may also enable rapid fault detection. An advantage of the invention, as opposed to certain prior art methods in which frequent calibration is contra-indicated, is that there can be almost no noticeable communication signal degradation and very little bandwidth overhead associated with calibration. An indirect advantage is that the system as a whole may be designed to tighter calibration tolerance limits, which may enable greater range or user density.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:-

Fig. 1 is a simplified schematic overview of a mobile telecommunications base station in which the invention can be employed;

Fig. 2 is a schematic overview of part of a modified system of Fig. 1 embodying the invention.

Referring to the simplified schematic diagram of Fig. 1, a mobile telecommunications base station comprises signal processing circuitry 10 coupled to a transmitter antenna array 20 via transmission lines 21 and to a receiver antenna array 22 via transmission lines 23. The antenna arrays 20 and 22 may be physically distinct, as shown, in which case they will normally, but need not necessarily, be located in a close physical proximity to each other. Alternatively, a single physical array may be used for both transmission and reception, with appropriate duplexing circuitry. The antenna arrays are in radio communication with a plurality of mobile

telephones 30a, 30b or other mobile communication devices. The base station signal processing circuitry 10 is coupled to a core telecommunications network 11, for example, by optical fibre, electrical connections or a microwave link.

The base station circuitry 10 includes a baseband digital signal processor 12 for processing signals from the communication network to be transmitted to a mobile device and for processing received signals for transmission to the telecommunications network. The digital signal processing circuitry will normally include a beam forming network and will perform code generation. The output of the digital signal processor passes through digital to analogue converters 14 and an array of up converters 16 for conversion from a baseband signal (for example a chip rate of a few megahertz, e.g. 4.096MHz) to a power level and frequency suitable for transmission (for example a few watts or tens of watts at the order of 1-2 GHz, these parameters depending on the assigned communication band). The signals received from the antenna array are amplified in low-noise amplifiers down converted and demodulated by down converters 18, then supplied to analogue-to-digital converters 19 for processing via the baseband digital signal processor 12.

As used herein, the term "up converter" is preferably used to denote the analogue transmitter chain circuitry, which will usually include a modulator such as a QPSK modulator and a power amplifier. Similarly, the term "down converter" is preferably used to denote the analogue receiver chain circuitry, which will usually include a low noise amplifier and a demodulator.

The base station circuitry 10 will normally include apparatus for correcting phase and amplitude distortions by applying pre-programmed correction factors (not shown). This apparatus may be provided, for example, as a network of discrete phase shifters or may be partially or completely integrated in the baseband digital signal processor 12 or the up converters

Correction phase & amp

16 and the down converters 18.

The antenna arrays may have any desired configuration, for example linear or circular with any desired number of elements, typically between about 2 and 10, and may extend in one dimension or two dimensions.

As described thus far with reference to Figure 1, the apparatus may be largely or entirely conventional and may be based on any of the apparatus described, for example, in WO 95/34103 or GB-A-2313523, the disclosures of which are herein incorporated by reference.

The invention is preferably employed in a system conforming to the ETSI UMTS Terrestrial Radio Access (UTRA) standard or the Japanese W-CDMA system, which is being standardised by ARIB, or derivatives thereof. The relevant standards, with which one skilled in the art will be familiar, are incorporated herein by reference.

Referring to Fig. 2, the modifications and/or additional components used in the calibration of a base station for a mobile telecommunications system in accordance with a preferred embodiment will now be described. As mentioned above, the modifications may be applied independently to calibration of transmitter-side circuitry or receiver-side circuitry, or, advantageously, both.

Considering first the receiver-side circuitry, as described above, down converters 18 receive signals from receiver antenna array 22 via transmission lines 23 and the outputs of the down converters 18 are supplied, in the conventional manner, to circuitry for processing received communication traffic. In the preferred embodiment, a calibration signal (the origin of which will be described further below) is injected at radio frequency by means of a coupling 100 in each transmission line 23, the couplings being ideally located physically close to the antenna array 22. In addition to

Calibration signal

being passed to the communication signal processing equipment, the outputs of the down converters are supplied to a calibration signal processor 108 used for calibrating the down converters in accordance with the preferred embodiment, as will be described further below.

Calibration signal processor

Considering next the transmitter-side circuitry, as described above, up converters 16 receive baseband communication signals for transmission from the digital signal processor 14 and produce outputs for coupling to transmitter antenna array 20 by transmission lines 21. In addition to communication signals, a calibration signal (the origin of which will be described further below) is injected, most preferably by processing in the digital domain, into the signal stream supplied to each up converter 16. The outputs of each up converter is sampled at radio frequency by means of a coupling 112 in each transmission line 21, the couplings being ideally located physically close to the antenna array 20.

The overall operation of the calibration apparatus is under the control of the calibration controller 105 which controls generation of calibration signals, analysis and other functions, as will be described further.

Generation of the calibration signals will now be described. In the preferred embodiment, calibration signals are provided for the receiver-side circuitry by means of a calibration signal generator 107 which supplies a single signal to a divider 110. The divider provides individual signals for each directional coupler 100 coupled to the transmission lines 23 coupling signals from the receiver antenna array 22 to the down converters 18. It is also possible to couple the calibration signal by means of external antennae, for example mounted adjacent the antenna elements of the antenna array.

External antenna

The calibration signal comprises "dummy" data coded using an uplink spreading code not assigned to an active mobile device 30a, 30b, but preferably having the same format as a signal which might be transmitted

dummy

by a mobile device (other formats may, however be employed). The signal may be formatted as a voice or a data signal. Normally, expected distortions for both voice and data signals would be similar, so only a single type of calibration signal need be used, but provision may be made for altering the packet format. Where, as in the preferred embodiment, the same calibration signal generator is used to generate signals for calibration of transmitter-side circuitry, the receiver-side calibration signal is preferably of a similar format, to simplify design.

low level

The calibration signal is preferably injected at as low a level as possible, to minimise interference. The required level is determined by the integration time and the signal to noise ratio after integration required for accurate phase and amplitude measurements. Typically, the power level will be similar to the level of (clear) signals received from the antenna array, for example equivalent to a single user signal at full cell loading.

Turning now to the calibration signal for the transmitter side, the same calibration signal generator 107 provides separate calibration signals for each transmitter chain; these are digitally summed with communication traffic and fed to the up converters 16. The calibration signal is preferably injected at as low a level as possible compatible with adequate signal to noise ratio, to minimise interference with communication traffic signals. The calibration signals are supplied as data coded with a single OVSF short code but a different data sequence for each up converter 16, so that the signals are mutually orthogonal when integrated over a 10ms data frame period. The data sequences may be selected from Orthogonal Gold codes in a known manner. Orthogonal Gold codes are not entirely orthogonal, and it is preferable to employ Walsh codes.

Most advantageously, we have found that orthogonality can be readily achieved by extending the OVSF code tree, based on the method described in section 5.3.2.2.1 of the UTRA RTT. Thus, if c0 is a 256 length OVSF

code calibration signals for 2 elements can be generated as follows:

$$s0 = [\ c0 \ \ c0\ ]$$
$$s1 = [\ c0 \ {-c0}\ ]$$

where s0 and s1 will each be of length 512 chips and would repeat periodically over the measurement period. For four elements, the following codes could be used:

$$s0 = [\ c0 \ \ c0 \ \ c0 \ \ c0\ ]$$
$$s1 = [\ c0 \ \ c0 \ {-c0} \ {-c0}\ ]$$
$$s2 = [\ c0 \ {-c0} \ \ c0 \ {-c0}\ ]$$
$$s3 = [\ c0 \ {-c0} \ {-c0} \ \ c0\ ]$$

each of which are of length 1024 chips and would repeat over the measurement period.

It is preferable to use longer sequences instead of repeating shorter sequences, or to change the sequences used every frame, to randomise the interference caused to the traffic channels.

Analysis of the calibration signals will now be discussed. In the case of calibration of the receiver-side circuitry, the outputs of the down converters corresponding to the calibration signal are at baseband level and are similar to outputs corresponding to a signal received from a mobile device. If the apparatus is ideally calibrated, the signals should all be of identical phase and amplitude. Each signal is correlated with the transmitted signal to determine phase and amplitude relative to the transmitted signal, and these results are then correlated to obtain differences between each receiver. Similar techniques will normally be employed elsewhere in the base station, in the digital signal processor 12, to provide appropriate weighting to locate the origin of a pilot signal from a mobile device 30a, 30b; the results of this

identical phase & amplitude

differ

weighting

analysis are used to select signals preferentially from a given mobile device at a particular location, and to generate a user's beamforming weighting vector to direct donwlink signals towards the mobile device.

beamforming weighting vec

The calibration signal can be considered as emanating from a virtual mobile device equidistant from all antenna elements (or at some other predetermined position if the signals injected into the receiver chains differ by some known amount). The apparent location of the virtual mobile device which is the apparent source of the calibration signal therefore gives a measure of calibration errors.

virtual mobile dev

* correction factor

The correction factors stored for the receiver-side circuitry may be adjusted (for example by gradual variation, or by calculating new parameters directly) following analysis until equal phase and amplitude signals are obtained from each down convertor.

In the case of calibration of the up-convertors, it will be apparent that the outputs of the up-convertors, sampled by the couplers 112, are at radio frequency. Whilst analysis of these signals could, in principle, be performed directly, it is more convenient to analyse these signals in the digital domain in the same way as the receiver-side signals are analysed. This, of course, requires down-converting the signals, and this must be done without introducing further unknown errors. In the preferred embodiment, the signals are combined directly at radio frequency in combiner 111 for down conversion by dedicated calibration down converter 104, which supplies signals to the calibration signal processor 108 in addition to the signals received from the other down converters.

It is preferred to use a dedicated down converter for calibration, although an existing receiver could be made use of if the transmitted signals are suitably attenuated and frequency translated.

The use of a combiner 111 allows a single calibration down converter to be provided, which reduces components and avoids the need to maintain or check calibration of the separate down converters that would otherwise be required. Another advantage of combining the signals is that simultaneous calibration of all up converters is possible. As alternatives to the above described arrangement, however, a dedicated calibration down converter could be provided for each up converter, or the output of the up converters could be fed sequentially to the input of the calibration down converter.

Because, as discussed above, the calibration signals are mutually orthogonal, the combined signals can be analysed in the digital domain to identify individual transmitter chain signals. The individual signals can then be correlated to identify phase and amplitude differences in an analogous manner to analysis of the signals from different receiver chains.

After extracting the signals from each transmitter chain, the correction factors for the transmitter-side circuitry are adjusted until all signals are of equal phase and amplitude (or phase and amplitude corresponding to the injected signals, if these have differing phases and amplitudes).

With the above described arrangement, calibration is effectively transparent and causes minimal disruption to communication traffic (there is only the overhead associated with carrying each calibration signal, which will normally be small in comparison to the total volume of traffic). It is therefore possible to carry out regular calibration, and minor drifts for example due to drifts in local oscillators in the analogue circuitry can be accurately tracked. It is even possible to carry out effectively continuous calibration, by continually transmitting frames carrying the calibration signal. However, since adjustment of the error-correcting circuitry will normally take a finite time to be effective (where error correction is performed digitally, it may be possible to achieve this virtually instantaneously), it is generally desirable to perform calibration only every alternate frame or to transmit the calibration

signal for only a part of a frame and leave some portion (for example a time slot) in which to effect adjustment of calibration.

Although the invention is most advantageously applied in the context of a CDMA system, where the use of a scrambling code to encode the calibration signal allows effective calibration to be performed, the invention could be extended to FDM or TDM systems.

Whilst described in the context of a mobile telephone system base station, the invention is also applicable to other systems with antenna arrays, and could be used in a mobile device with two or more antennae.

Each feature disclosed above may be independently provided, unless otherwise stated.

Claims

1. A method of calibrating at least a portion of a chain of transmitter or receiver components coupled to an element of an antenna array and passing a plurality of communication traffic signals to or from the antenna array element, the communication traffic signals being coded according to a coding scheme to be substantially mutually orthogonal, the method comprising:

injecting a calibration signal into the chain, the calibration signal being coded according to said coding scheme to be substantially orthogonal to said communication traffic signals;

extracting the injected signal; and

calibrating said portion based on the extracted signal.

2. A method according to Claim 1 for calibrating components of a CDMA communication system, wherein the calibration signal is transmitted with one or more spreading codes different from codes assigned to communication traffic.

3. A method according to Claim 2, wherein the calibration signal is injected using a single Orthogonal Variable Spreading Factor (OVSF) short code .

4. A method according to any preceding claim for calibrating transmitter-side circuitry, wherein individually identifiable calibration signals are supplied to each of a plurality of transmitter chains.

5. A method according to Claim 4 as dependent on Claim 3, wherein the single short code is further modulated with a further data sequence which varies between elements of the antenna array so that the combinations of short code and data sequence supplied to each transmitter chain are mutually orthogonal.

6. A method according to Claim 4 or Claim 5 wherein the outputs of a plurality of transmitter chains are combined at radio frequency and the calibration signals are extracted from the combined output by a single receiver.

7. A method according to any preceding claim for calibrating transmitter-side circuitry, wherein the calibration signal is injected in the digital domain.

8. A method according to any preceding claim for calibrating transmitter-side circuitry in which the output of the circuitry is coupled to the antenna element by means of a transmission line, wherein the output of each transmission chain is sampled by means of a radio frequency coupling coupled to the transmission line.

9. A method according to any of Claims 1 to 3 for calibrating receiver-side circuitry, wherein the calibration signal is injected by means of a radio frequency coupling coupled to a transmission line receiving signals from a corresponding antenna element.

10. A method according to any of Claims 1 to 3 or 9 for calibrating receiver-side circuitry, wherein the calibration signal is extracted in the digital domain.

11. A method according to any of Claims 1 to 3, 9 or 10, wherein the calibration signal is coded with a scrambling code substantially orthogonal to scrambling codes assigned to remote devices.

12. A method according to any preceding claim for calibrating a mobile telecommunication base station.

13. A method according to any preceding claim wherein the calibration signal is both injected and extracted locally.

14. A method according to any preceding claim, wherein said calibration signal is injected and a measure of calibration is obtained regularly or substantially continuously.

15. A method according to Claim 14, wherein said communication traffic signals are transmitted in frames, preferably of less than 1 second duration, and the calibration signal is injected substantially every predetermined number of frames, preferably every frame.

16. Apparatus for calibrating at least a portion of a chain of transmitter or receiver components of communication apparatus arranged for coupling to an element of an antenna array to pass a plurality of communication traffic signals to or from the antenna array element, the communication traffic signals being coded according to a coding scheme to be substantially mutually orthogonal, the apparatus comprising:

means for injecting a calibration signal into the chain, the calibration signal being coded according to said coding scheme to be substantially orthogonal to said communication traffic signals;

means for extracting the injected calibration signal; and

means for determining at least one calibration parameter for said portion based on the extracted signal.

17. Communication apparatus arranged for coupling to an antenna array having a plurality of elements, the apparatus comprising:

a plurality of chains of transmitter components and receiver components, each chain being arranged for coupling to a respective element of the antenna array and arranged to pass a plurality of communication traffic signals to or from the antenna array element, the communication traffic signals being coded according to a coding scheme to be substantially mutually orthogonal;

means for injecting a calibration signal into the chain, the calibration

signal being coded according to said coding scheme to be substantially orthogonal to said communication traffic signals;

means for extracting the injected calibration signal; and

means for determining at least one calibration parameter for said portion based on the extracted signal.

18. Apparatus according to Claim 16 or 17 arranged to inject individually identifiable calibration signals to each of a plurality of transmitter chains.

19. Apparatus according to Claim 18, wherein the calibration signal is coded with a single OVSF short code and comprises a data sequence which varies between transmitter chains so that the combinations of short code and data sequence supplied to each transmitter chain are mutually orthogonal.

20. Apparatus according to any of Claims 16 to 19 including means for combining the outputs of a plurality of transmitter chains at radio frequency and a single receiver for extracting the calibration signals from the combined output.

21. Apparatus according to any of Claims 16 to 20, including digital signal processing means for processing baseband digital communication traffic signals received or to be transmitted, said digital signal processing means being adapted to inject said calibration signal into the signals to be transmitted or to extract said calibration signal from signals received.

22. Apparatus according to any of Claims 16 to 21 including a transmission line for coupling a receiver or transmitter chain to an element of the antenna array, the transmission line including a radio-frequency coupling for injecting or sampling at radio frequency a signal including said calibration signal.

23. Apparatus according to any of Claims 16 to 22 arranged to inject said calibration signal regularly or substantially continuously.

24. A mobile telecommunications base station including apparatus according to any of Claims 16 to 23.

25. A method of calibrating communication apparatus or communication apparatus substantially as herein described, with reference to Fig. 2 of the accompanying drawings.

The Patent Office

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INVESTOR IN PEOPLE

Application No: GB 9821779.7 **Examiner:** John Betts
Claims searched: 1-25 **Date of search:** 17 August 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H1Q (QFF, QFJ, QHE, QHX) G1U (UR2910) H4L (LFM)

Int Cl (Ed.6): H01Q3/26 G01R29/10 H04B17/00

Other: On-line: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
Y	US5063529	(Texas Instruments) see references to calibration on-line	1,16-17 at least
Y	WO98/42093 A1	(Matsushita) use of spread spectrum calibration signal	1,16-17 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.